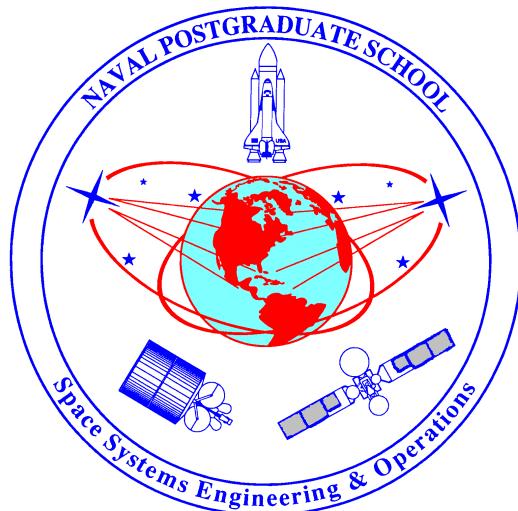




NPSAT1

Spacecraft Architecture and Technology Demonstration Satellite

Brief to Space Systems Seminar



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Introduction

- Space Systems Education at NPS
- Small Satellite Design Studies Background
- NPS Facilities
- NPSAT1
 - Mission Overview
 - Bus Architecture
 - Experiment Platform



NPS Space Program

- Space Systems Operations
- Space Systems Engineering
- Space-Related Research
 - Spacecraft Technology
 - Space Environmental Effects on Semiconductors
 - Spacecraft Design



NPS SmallSat Program Background

- “Hardware-in-the-loop education”
- Space-flight experiments
 - Space thermo-acoustic refrigerator (STAR)
 - Ferroelectric materials in space
 - “Piggyback” experiment
 - APEX & DATASAT-X



NPS SmallSat Program Background

- Complete spacecraft development
 - Full life-cycle development
 - Design, development, integration & test
 - Launch and on-orbit operation
 - PANSAT (Discovery Shuttle, STS-95, 1998)
 - Microsatellite (digital communications)
 - Still operating (beyond 2-year design life)



PANSAT Launch & Deploy (Oct. '98)





NPS Facilities



Vibration Shaker



Electronics
Development &
Test

Thermal-
Vacuum
Chamber





NPS Facilities (cont'd.)

- PANSAT ground station
- EMI shielded enclosure
- Solar simulator
- CAD/CAE Tools
- Tensile-testing
- Spherical air bearing
- Battery test
- Clean room (class 10,000)
- N₂ -purged, component storage
- Precision machining (CNC mills)
- Other test instruments (RF, digital, analog)



NPSAT1 Mission Overview

- Objectives:
 - Educational tool
 - Demonstrate low-cost, COTS architecture
 - PC-compatible command & data handling (C&DH) subsystem
 - POSIX-compliant operating system (Linux)
 - Demonstrate COTS technology for smallsats
 - FERRO RAM
 - Li-ion polymer batteries



NPSAT1 Mission Overview

- Objectives (cont'd.)
 - Experiment platform
 - Two NRL experiments
 - Coherent electromagnetic radio tomography (CERTO) beacon
 - Langmuir Probe
 - Three NPS experiments
 - Configurable processor experiment (CPE)
 - COTS micro-electromechanical systems (MEMS) rate sensor
 - COTS visible imager (digital camera)



NPSAT1 Mission Overview

- 2-year mission life (min.)
- Orbit: 550 km-800 km, circular
30°-80° inclination
- Secondary payload on a number of launch carriers
 - Shuttle SHELS, EELV/ESPA, etc.
 - Targeting EELV/ESPA, MLV-05 (600 km circ.,
x 38° inclination)
- NPS command ground station



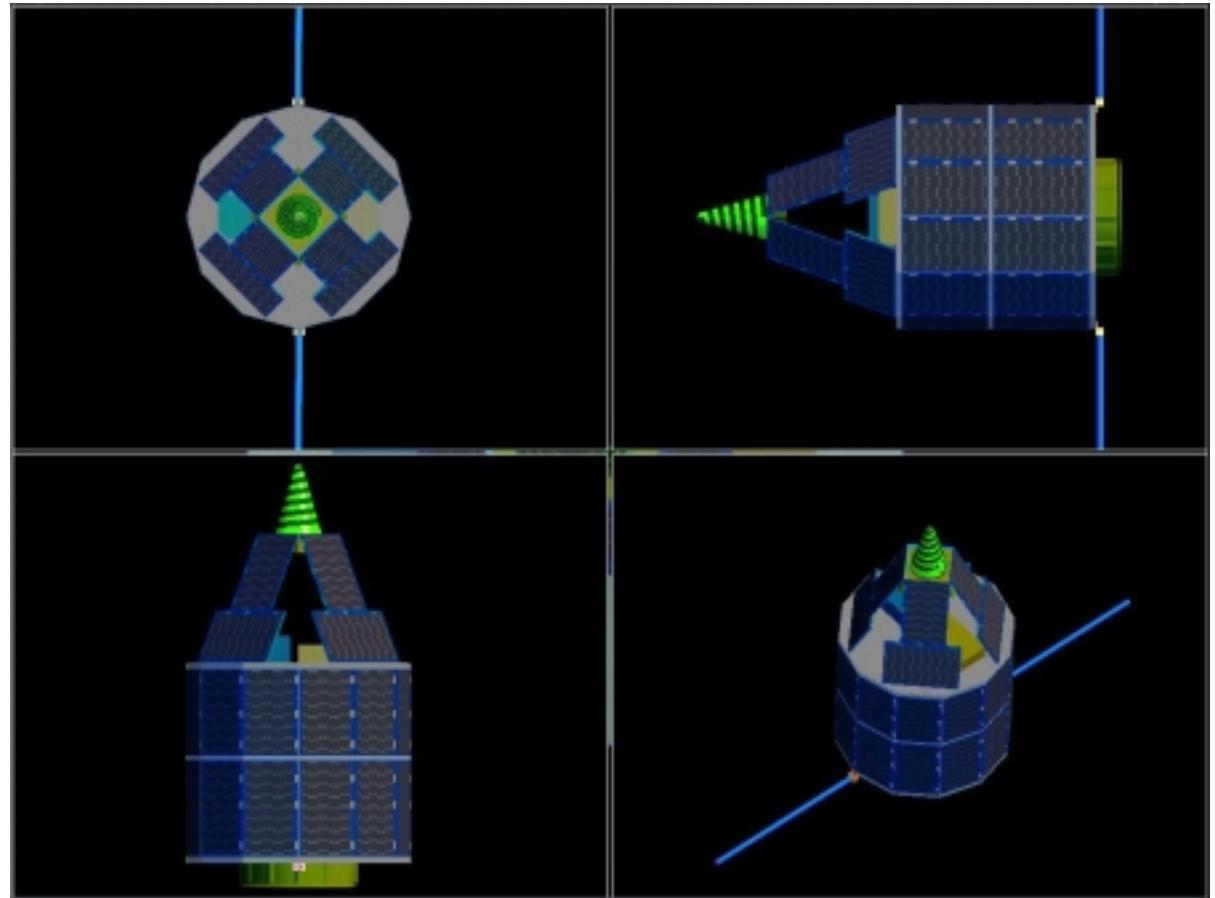
NPSAT1 Design Objectives

- Low-cost design (< \$1M hardware cost)
- Utilizing existing hardware (structure & solar cells)
- Power mgmt.: duty cycle electronics
 - Subsystems
 - Experiment payloads
- “Single-string” design



NPSAT1 Configuration

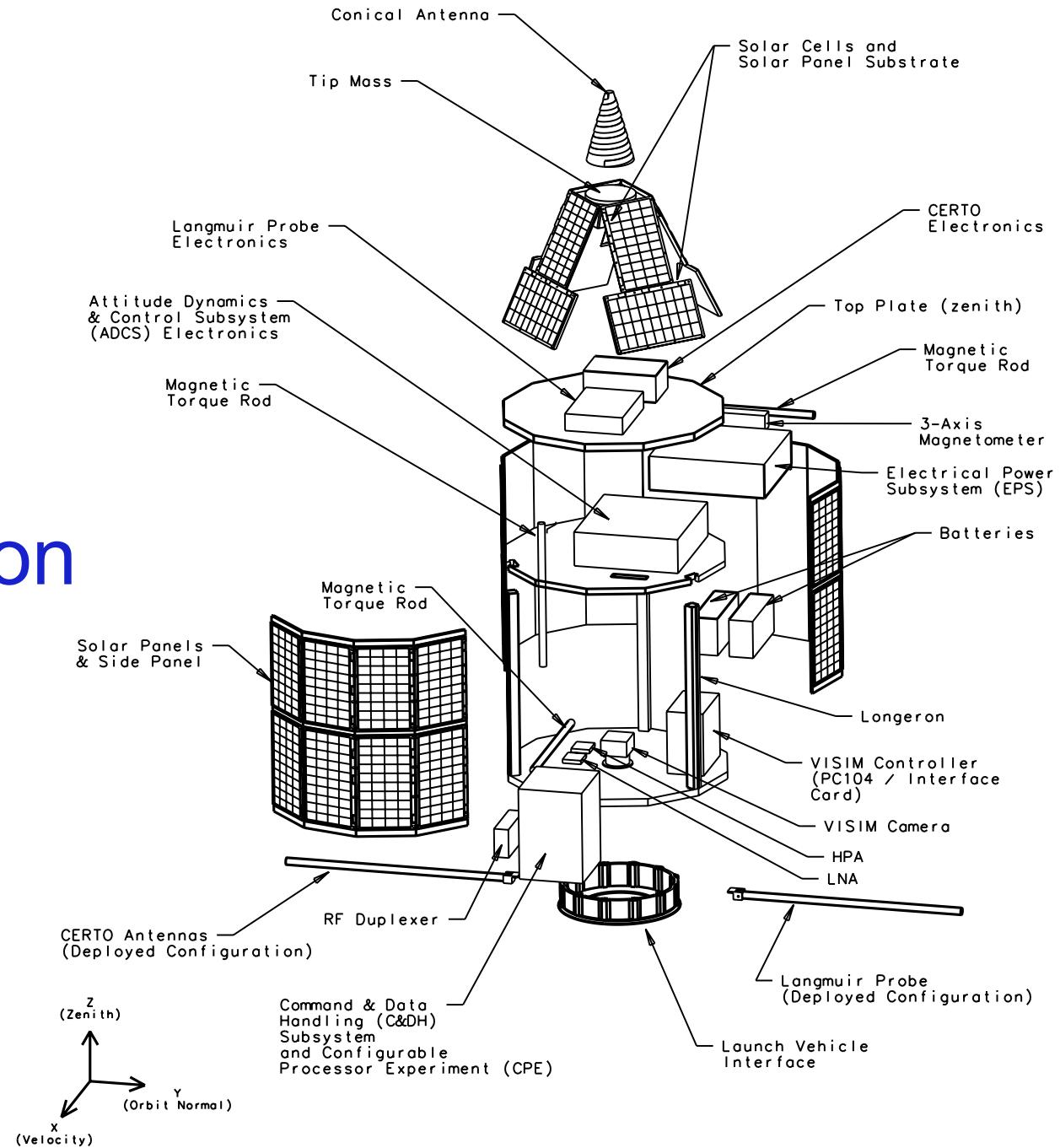
- Overall dimensions:
93 cm (37 in.) height
x 50 cm (20 in.) diam.
- CERTO deployable antenna
- Deployable Langmuir probe
- 2-inch (height) launch vehicle interface





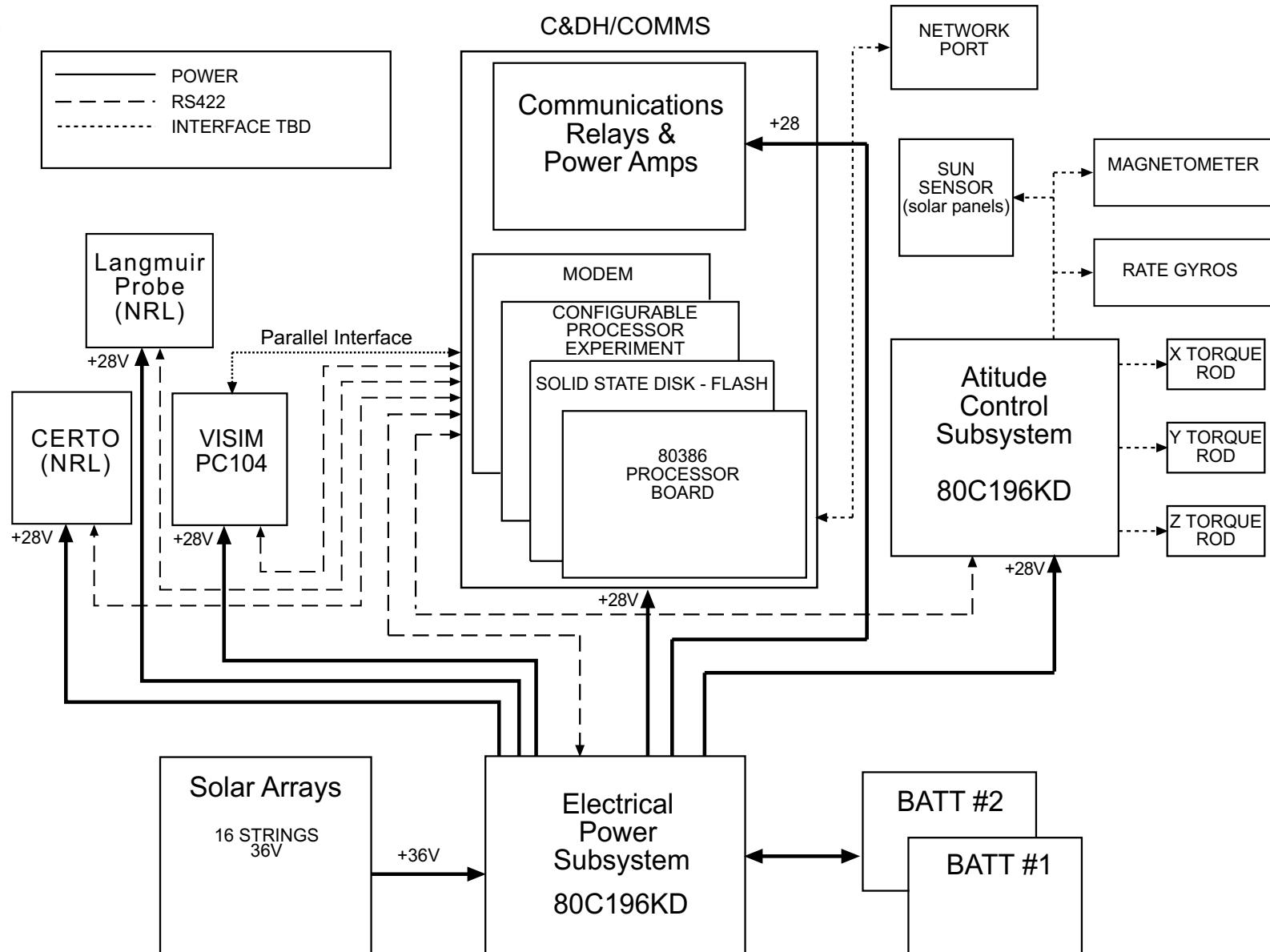
NPSAT1

Configuration





System Block Diagram

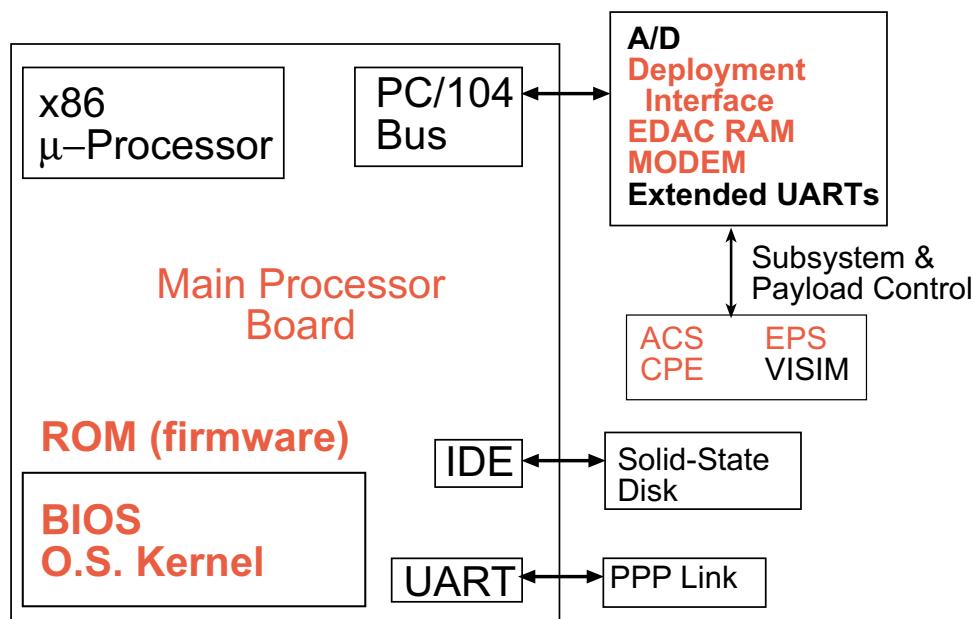


30 Apr 2001



NPSAT1 Design Overview: C&DH

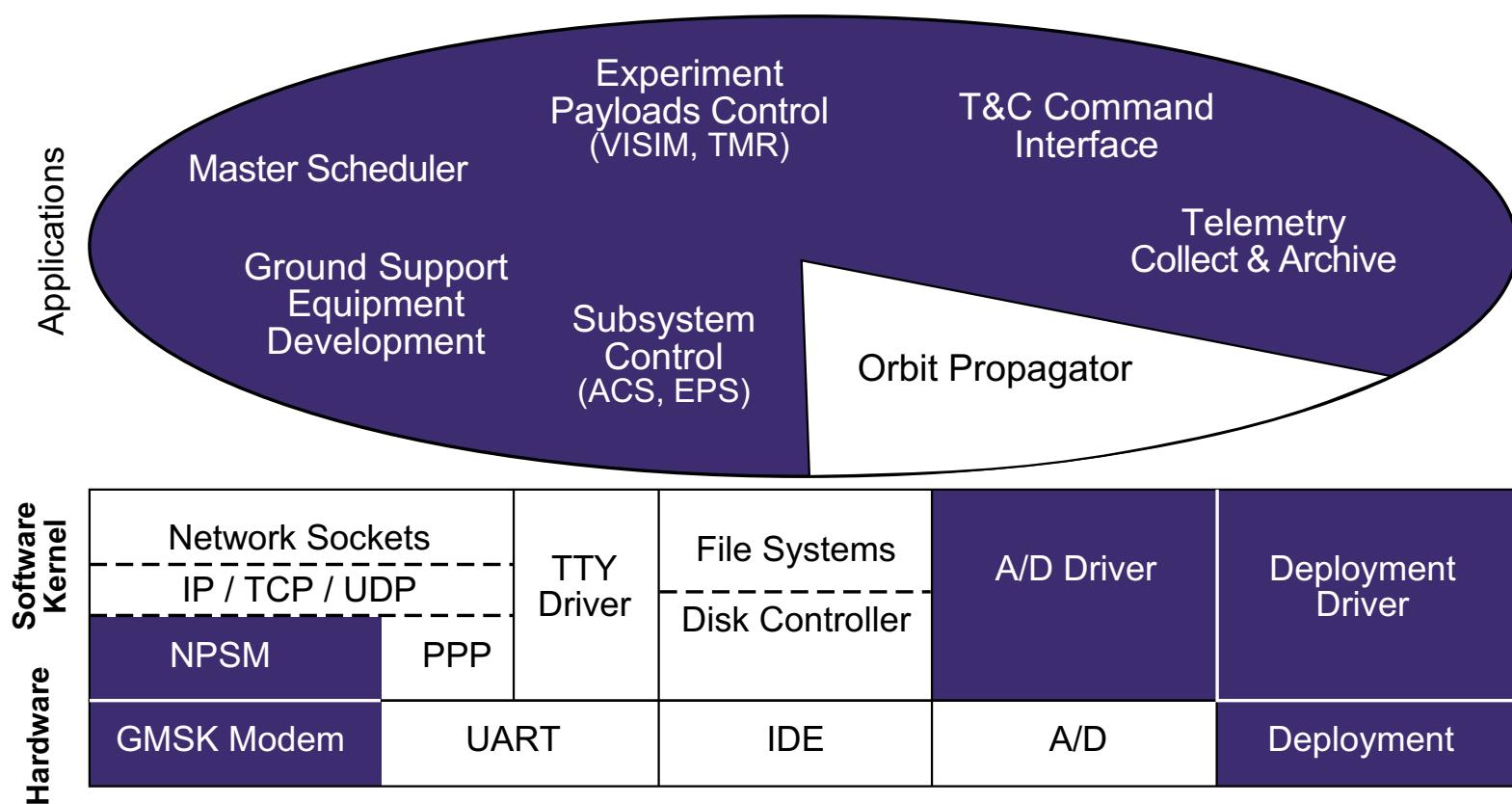
Command & Data Handling Hardware



- C&DH
 - X86 processor (Intel386EX)
 - Error-detection-and-correction (EDAC) RAM
 - PC/104 bus interface
 - IDE disk storage
 - Serial test interface via PPP



NPSAT1 Design Overview: Software



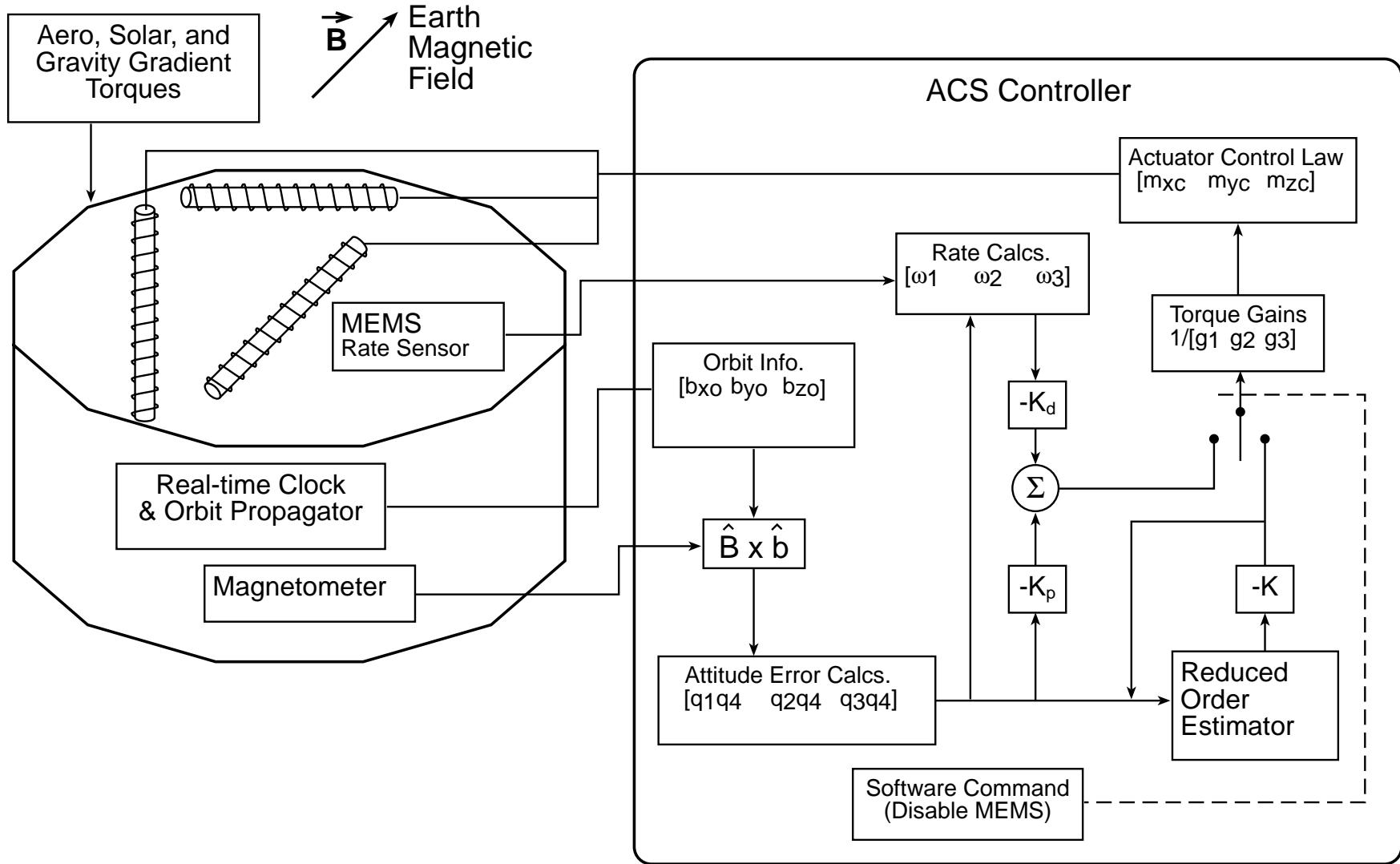


NPSAT1 Design Overview: ACS

- ACS
 - ±10° pointing accuracy
 - ±0.66°/sec max. rates
 - Similar control electronics as EPS
 - Actuators: magnetorquers
 - Sensors: 3-axis magnetometer and solar panel currents
 - On-board orbit propagator



ACS Block Diagram





NPSAT1 Design Overview: EPS

- Rad-hard parts: micro-controllers & RAM in both EPS & ACS
- Electrical Power Subsystem (EPS)
 - 28V bus
 - Silicon solar cells / Li-ion polymer batteries
 - DC/DC conversion at the subsystem
 - Watchdog timer for resetting C&DH

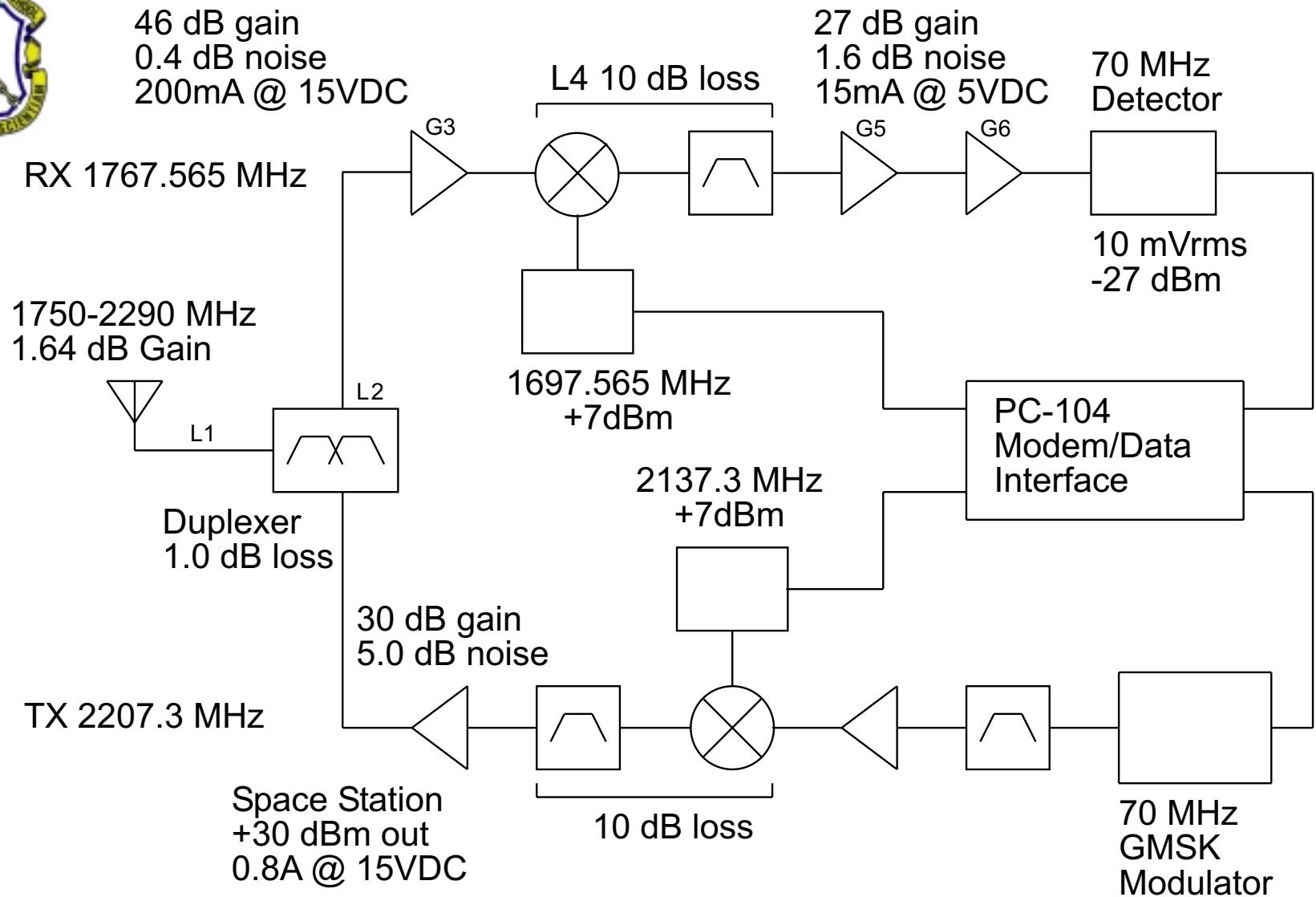


NPSAT1 Design Overview: Communications



Modem Development
System

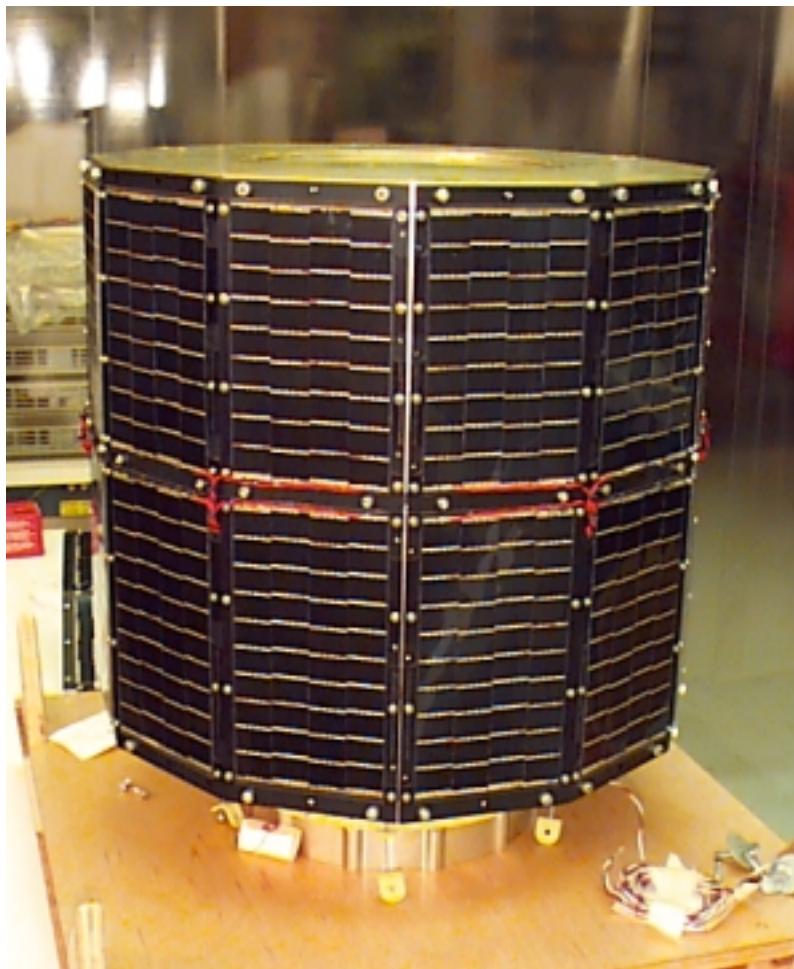
- Communications Subsystem
 - GMSK modulation
 - Full Duplex
 - 100 kbps data rate
 - Uplink at 1.767 GHz
 - Downlink at 2.207 GHz



NPSAT1 Spacecraft RF Modem Interface



NPSAT1 Design Overview: Structure



- Mechanical Structure
 - Robust, aluminum frame & panels
 - Inherited parts from excess property
 - Necessary modifications
 - Launch vehicle interface
 - Add'l solar panels
 - Component mounting
 - VISIM FOV



NPSAT1 Design Overview: Structure

Mode 1 Frequency: 41.85436 Hz



Item	Mass (kg)	Weight (lbs.)
Spacecraft Structure	38.8	85.30
Solar Panels	8.0	17.65
C&DH/Modem and CPE	4.3	9.50
EPS Electronics	3.6	8.00
Batteries (2)	3.6	8.00
ACS Controller	3.6	8.00
Torque Rods (3)	4.2	9.24
Magnetometer	0.1	0.31
COMMS Components	2.5	5.50
CERTO Electronics	0.9	2.00
CERTO Antenna	0.2	0.47
Langmuir Probe Electronics	1.8	4.00
Langmuir Probe (Deployable)	0.2	0.47
VISIM Controller	0.9	2.00
VISIM Camera	6.7	14.64
MEMS	1.4	3.00
Total	80.9	178.08

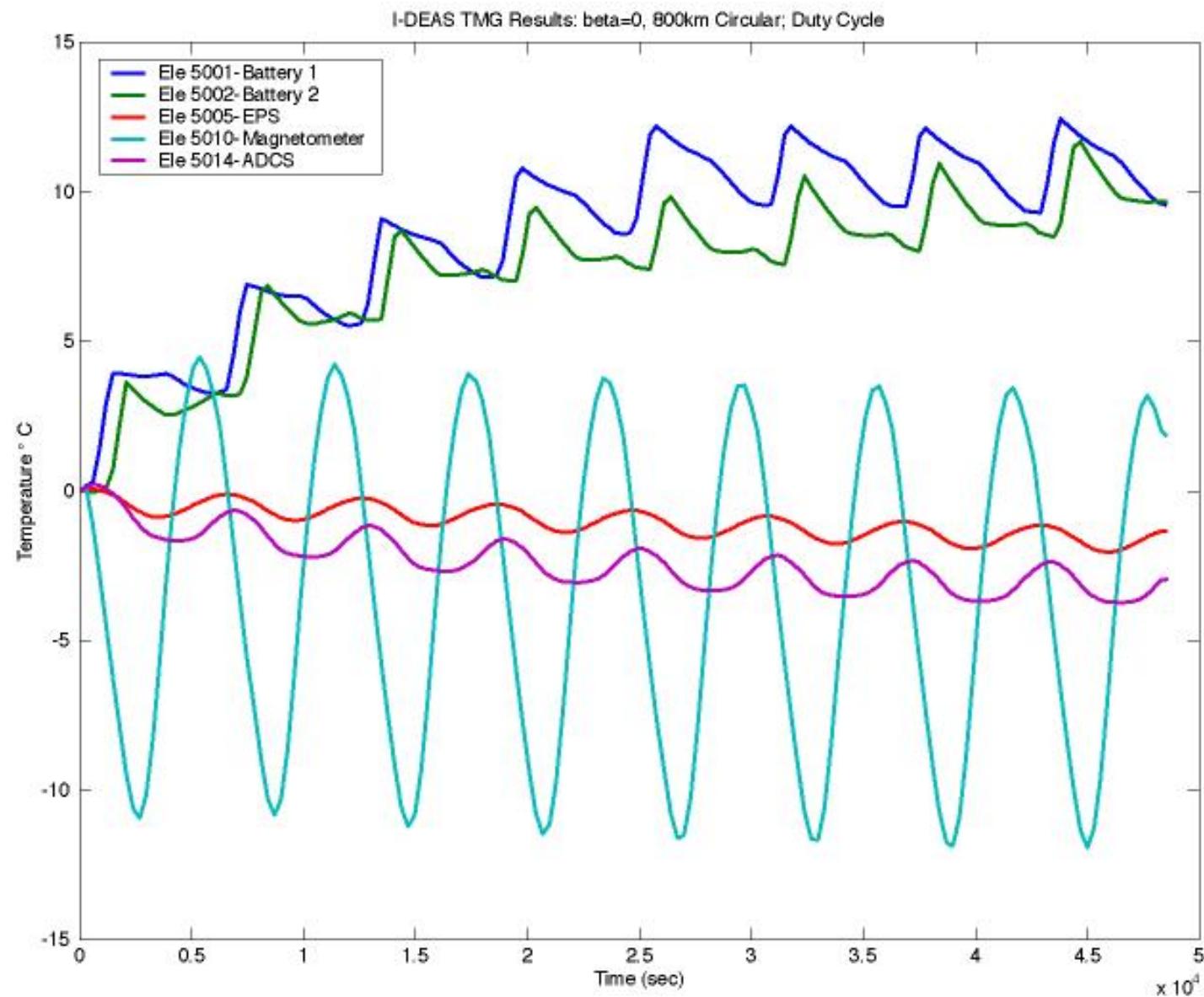


NPSAT1 Design Overview: Thermal

- Thermal
 - Li-ion polymer batteries: 0° to 45° C
 - Electronics: -25° to 85°C (industrial grade)
 - Preliminary analysis: cold environment
 - Average spacecraft power: 18 W
 - Batteries requiring thermal isolation & heaters

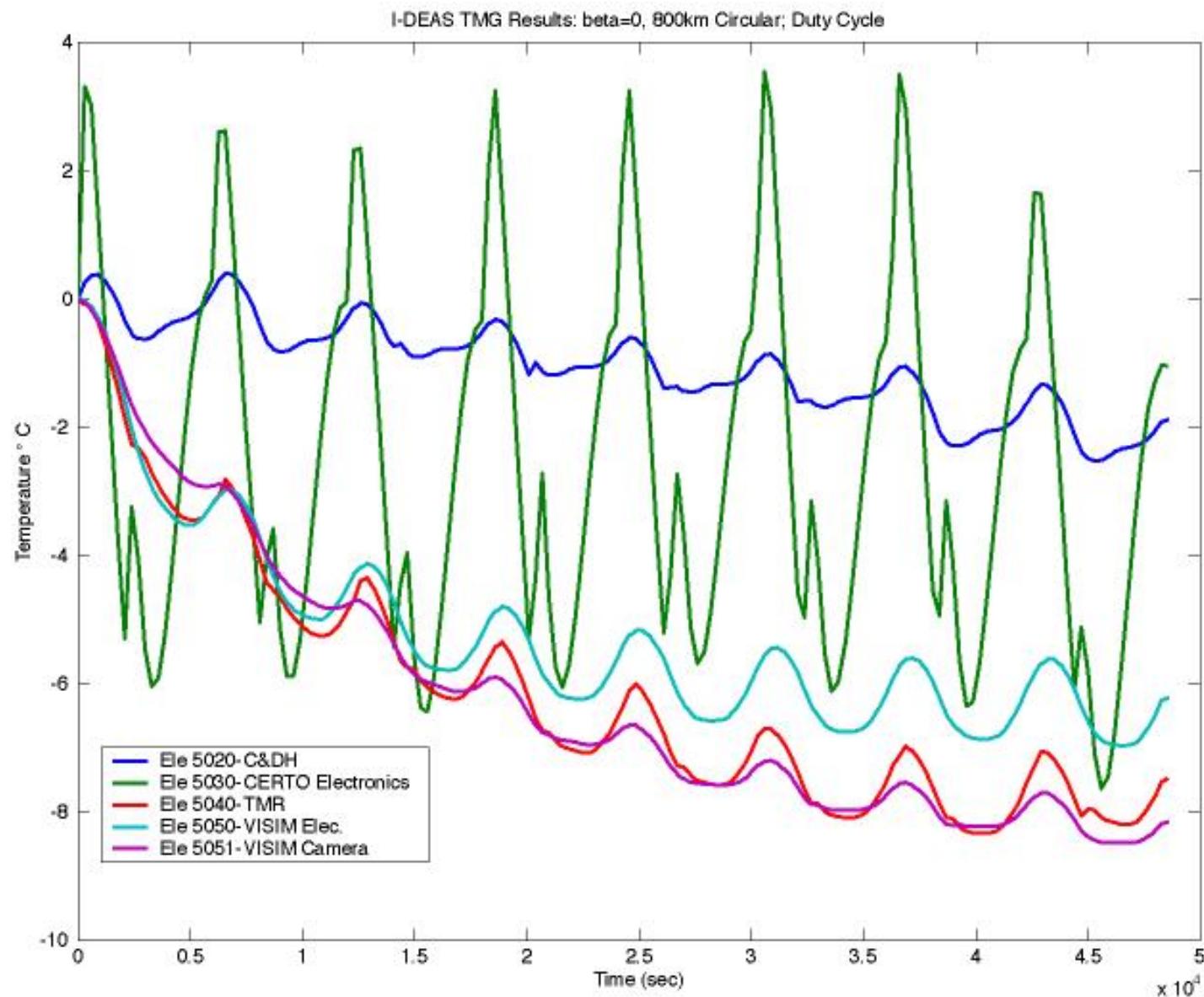


NPSAT1 Subsystem Temperatures





NPSAT1 Subsystem Temperatures





NPSAT1 Design Overview

- Experiments

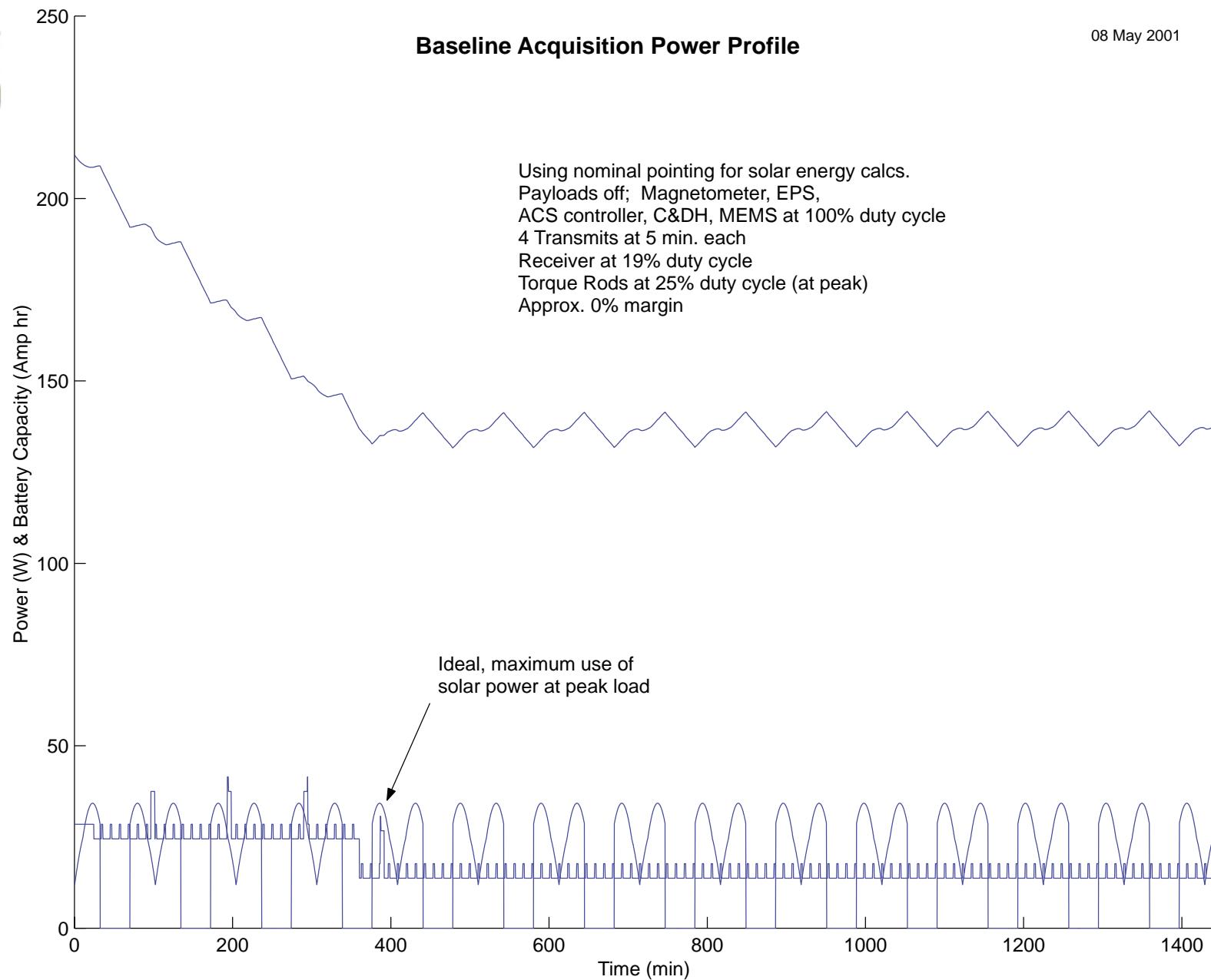
- Must be able to duty-cycle (power off)
- Can use telemetry & command (T&C)
- On-board memory storage available
- Can use real-time clock



Baseline Acquisition Power Profile

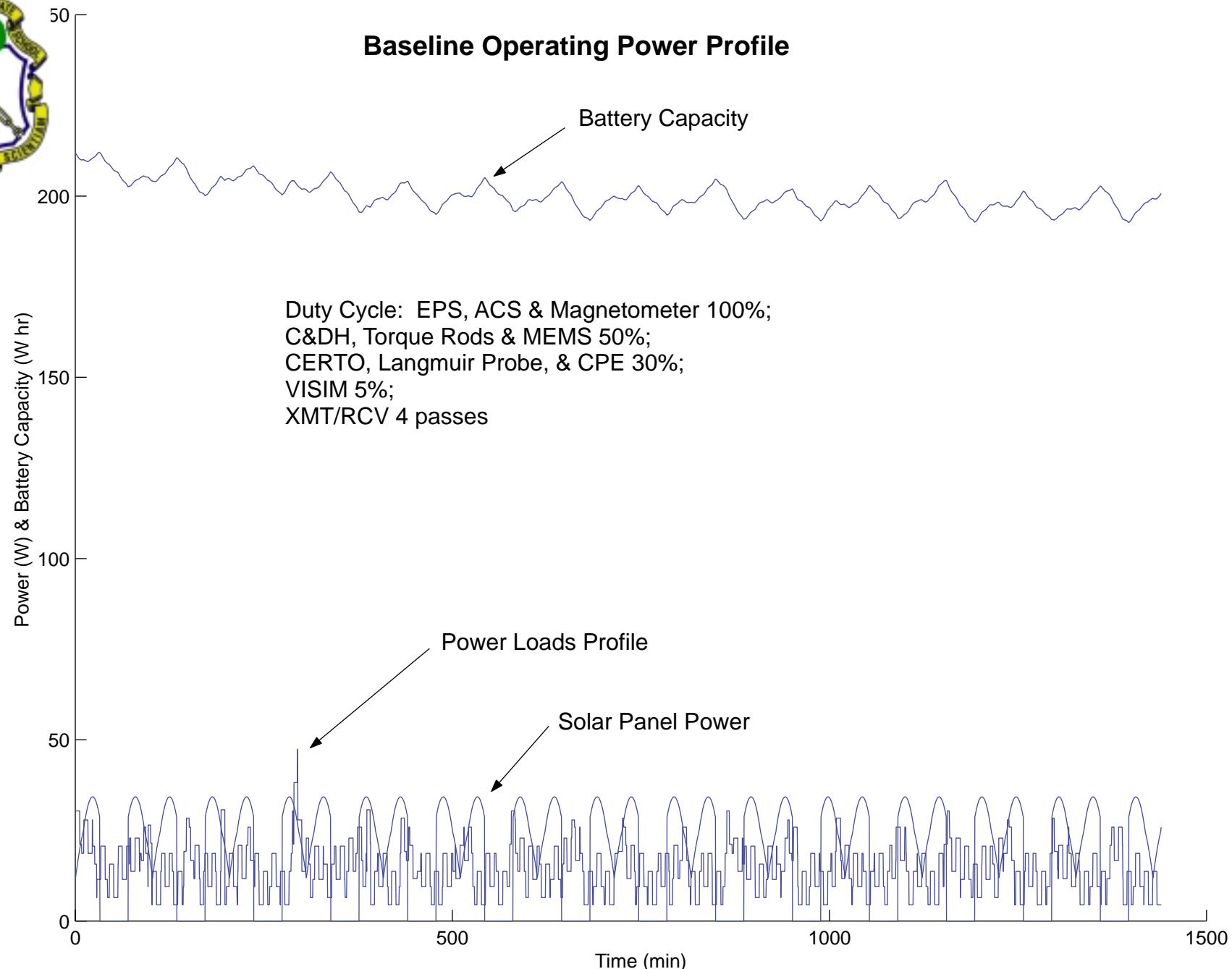
08 May 2001

Using nominal pointing for solar energy calc.
Payloads off; Magnetometer, EPS,
ACS controller, C&DH, MEMS at 100% duty cycle
4 Transmits at 5 min. each
Receiver at 19% duty cycle
Torque Rods at 25% duty cycle (at peak)
Approx. 0% margin





Baseline Operating Power Profile





NPSAT1 Experiments

- NRL Experiments
 - Coherent Electromagnetic Radio Tomography (CERTO)
 - Two-frequency beacon
 - Ground stations measuring phase and amplitude scintillations
 - Total electron content (TEC) in ionosphere in plane of observation
 - Applications to radar, communications, navigation, surveillance

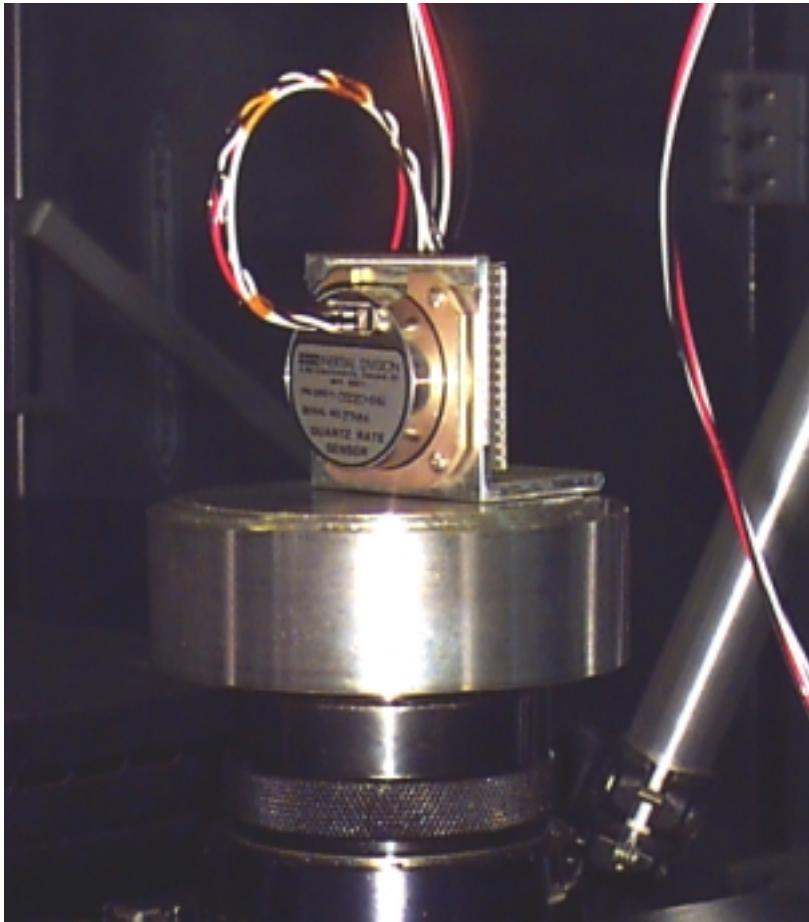


NPSAT1 Experiments

- NRL Experiments (cont'd.)
 - Langmuir Probe
 - Augments CERTO data
 - In-situ measurements at orbit altitude
- NPS Configurable Processor Experiment
 - Adaptable processor using FPGA
 - Non-volatile FERRO RAM for configuration memory
 - Add-on card within C&DH housing
 - Various applications (triple-modular-redundant computer, compression algorithms)



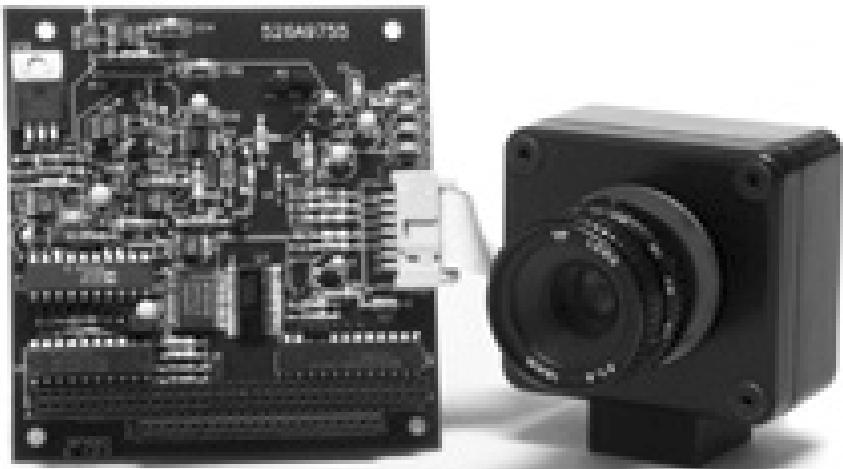
NPSAT1 Experiments



- MEMS rate sensor
 - Use COTS rate sensor
 - $\pm 5^\circ/\text{sec}$ range
 - Three sensors for 3-axis rates
 - $\pm 5 \text{ V}$ at $<80 \text{ mA}$ each
 - Gain flight experience w/ MEMS devices
 - Use during acquisition (low sensitivity at orbital rates)
 - Use on a power-available basis



NPSAT1 Experiments



PC/104 Camera

- COTS Visual Imager (VISIM)
 - PC/104 interface card & CCD camera
 - PC/104 cpu board
 - Array: 652 x 492
 - Raw image: Bayer format
 - Custom optics for < 100 m resolution



NPSAT1 Experiments

- COTS Visual Imager (VISIM) (cont'd.)
 - Generate data for officer students in space curricula
 - Research on-orbit processing of data (compression algorithms, etc.)
 - Educational outreach
 - Have k-12 schools ‘task’ satellite for images
 - Distribute images via Internet (World Wide Web)
 - ‘Spark’ interest in engineering / science



NPSAT1 Web Site

For more information . . .

<http://www.sp.nps.navy.mil/npsat1>